EFFECT OF GROUNDNUT SHELL ASH ON THE PARTICLE SIZE AND PLASTICITY CHARACTERISTICS OF BLACK COTTON SOIL

T. S. IJIMDIYA
Department of Civil Engineering, Ahmadu Bello University, Zaria. Nigeria.
[tom_ijim@gmail.com, tsijimdiya@abu.edu.ng]

ABSTRACT
The paper presents the results of a laboratory study on the effect of groundnut shell ash on the particle size distribution and plasticity characteristics of black cotton soil. Black cotton soil was treated with a maximum 10 % groundnut shell ash by weight of dry soil. The results show that there was a substantial reduction in the amount of fines content with higher doses of groundnut shell ash. The percentage of silt fraction in the natural soil was 91 % and on treatment with maximum 10 % groundnut shell ash content (by weight of dry soil) at optimum moisture content (OMC), the silt fraction was reduced to 1.3 %. The plasticity index increased from 38 to 75 % when treated with 10 % groundnut shell ash content by weight of dry soil. The results obtained place the soil below the Highway Research Board of America (1943) requirements of plasticity index of less than 50 %. The plasticity modulus (PM), plasticity product (PP) and the shrinkage modulus (SM) increased while the grading modulus (GM) decreased with higher doses of groundnut shell ash. However, the treated soil can be admixed with more potent stabilizer since its workability was improved by addition of 10% groundnut shell ash content by dry weight of soil.

KEYWORDS: *Particle size distribution, optimum moisture contents, fines content, groundnut shell ash contentsand black cotton soil.*

INTRODUCTION

Groundnut Shell Ash (GSA) is an agricultural waste product obtained from the milling of groundnut. Groundnuts are found extensively in the northern part of Nigeria where they are cultivated. During and after the harvest of groundnut, the shells are regarded as waste which when accumulated in large quantities in a particular area will constitute an environmental hazard. Therefore, the utilization of GSA as a possible stabilizer will go a long way in reducing the cost of stabilization of the deficient soil and also alleviate the environmental problem associated with the accumulation of the GSA in a large quantity in a particular area.

Nigeria contributes about 7% of world's groundnut production. In 2002, about 2,699,000 Mt of groundnut were produced in about 2,783,000 hectares of land in Nigeria. Meanwhile groundnut shell ash has been categorised as being a pozzolanic material (Alabadan et al, 2006). This study was aimed at evaluating the effect of groundnut shell ash treatment on the particle size and plasticity characteristics of black cotton soil.

The name black cotton soil is derived from the fact that cotton plant thrives well on it. The black cotton soils of north-eastern Nigeria derive their origin from basalts of the upper Benue trough which covers a wide area extending north and east of the Jos Plateau and from quaternary sediments of lacustrine origin from the Chad basin consisting mainly of shales, clay and shaly sediments (Jones and Holtz, 1973). Specifically, Nigerian black cotton soils are formed from the weathering of shaly and clayey sediments and basaltic rocks. According to Ola (Balogun, 1991a) the Nigerian black cotton soil contains more of the montmorillonite clay mineral with subsequent manifestation of swell properties and expansive tendencies. The soil is found in the north eastern parts of Nigeria, Cameroon, Lake Chad Basin, Sudan, Ethiopia, Kenya, South Zimbabwe and other Eastern African countries, India, Australia, South Western U.S.A., South Africa and Israel (Balogun, 1991b). Its colouris dark- grey to black probably due to iron and titanium compounds present. It is classified as an A-7-6 soil according to the AASHTO (Osinubi, 2006) classification system and has index properties that indicate an inadequacy for most practical engineering use. Expansive soils cause more damage to structures than any other natural hazard including earthquakes and floods (Osinubi, 1995). The amount of damage caused by expansive soils is alarming. In Nigeria, the damages caused by expansive soils are not documented; however, in the United States, it has been estimated that losses from expansive soils exceed two billion dollars annually (Osinubi and Medubi, 1997).

The properties of black cotton soil affect the performance of pavements built over such formations.This is because the index properties of these soils indicate a classification that shows inadequacy for use and does not meet the minimum design requirements for sub-grade material. In the north eastern part of Nigeria where these soils are predominant or wherever they occur, they cover an extensive area that avoiding them or finding a suitable replacement is not feasible. As a means of improving the geotechnical properties of black cotton soil ,lime, cement and admixture stabilization have been used to treat the deficient soil (Ola, 1983, Balogun, 1990, Osinubi, 1995, 1999, Osinubi and Medubi, 1997). Although the properties of this soil are appreciably improved, the cost of incorporating the conventional stabilizers is quite high. This high cost implication has aroused the thinking of research engineers to focus more on the use of potentially cost effective materials that are locally available to improve the properties of deficient soils (Osinubi, 2000a, 2000b, Osinubi and Medubi, 1997).

MATERIALS AND METHODS

Materials

Soil: Disturbed soil samples of the light gray tropical black clay used for this study were collected from Cham Local Government Area of Gombe State, Nigeria. Samples were collected at a depth of 1.5 m. The concentrations of the major detected oxides by weight using X-ray fluorescence analysis are given in Table 1.

Groundnut Shell Ash: The ash obtained from the burning of groundnut shell was sieved through BS No. 200 sieve (75 µm aperture). Up to 10% GSA was mixed with soil and lime to form different soil – lime - GSA mixtures. The oxide compositions of black cotton soil, GSA and cement are summarised in Table 1.

METHODOLOGY

The soil sample was subjected to various laboratory tests in order to determine its inherent physical and engineering properties. The tests were performed in accordance with BS. 1377(1990) and BS 1924 (1990) for the natural and stabilized soils, respectively.

Particle Size Distribution Characteristic

The particle size distribution of the natural soil was determined using both the sedimentation analysis and the dry sieving of the coarse fraction as specified by BS 1377 (1990) for cohesive soils. The soil sample was washed through BS No. 200sieve and the material retained was oven dried and sieved by agitating the material through a range of sieves from sieve No.7 or 2.4mm sieve and downwards while the material passing was turned into a sedimentation cylinder for hydrometer analysis. When the black cotton soil was treated with (0 - 12%) GSA at OMC; less than 10% of the material passed through BS No. 200sieve, and therefore did not meet the minimum requirement for sedimentation analysis to be done on the treated soil. The percentages of the soil passing were calculated in order to establish their particle size distribution. Grading modulus (GM) that captures the fine to medium sand fraction of the soil was computed using the following equation (Charman, 1998; TRRL, 1990).

$$GM = \left[\frac{300 - \%pas\sin g\ 2.4mm + \% < 0.425mm + \% < 0.075mm}{100}\right] \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (1)$$

Table 1: Oxide Compositions of Tropical Black Clay, Groundnut Shell Ash and OPC

Oxide	Concentration (%)		
	Tropical Black Clay	Groundnut Shell Ash	Ordinary Portland Cement*
CaO	1.96	14.05	63.0
SiO_2	62.10	38.89	20.0
Al_2O_3	18.15	10.28	6.0
Fe_2O_3	11.58	4.28	3.0
MgO	1.39	7.48	0.86
MnO	0.29	0.49	
Na_2O	0.07	0.28	1.0
K_2O	1.24	12.72	-
TiO_2	2.25	1.71	-
P_2O_5	0.39	6.53	-
LossonIgnition		4.20	1.0

* After Czernin(1962)

Plasticity Characteristics

The proportion of the material passing sieve with aperture 425 µm which was used for the determination of the liquid limit was also used for the determination of the plastic limit. A sample of the wet soil was taken and moulded between the palms of the two hands.The sample was rolled and sub-divided into two sub samples which was further sub-divided into four equal parts.Each of the portions formed was then rolled between the tips of the fingers and the surface of the glass. Sufficient pressure was then exerted to reduce the diameter of the thread to about 3 mm, as specified by the BS 1377 (1990). The rolled soil which formed a thread was rolled until it shared in both ways. The plastic limit was recorded as the average of the moisture contents obtained. The procedure was repeated for every successive increment in the concentration of the GSA. The plasticity index (PI) was computed as the numerical difference between the liquid limit (LL) and the Plastic Limit (PL). Other parameters associated with plasticity of the soil include (Charman, 1998):

Plasticity Modulus (PM) defined as the product of plasticity index and percentage of soil fraction passing BS No 40 sieve (i.e., % < 425 µm):

$$PM = PI * (\% < 425\mu m) \quad \cdots(2)$$

Plasticity Product (PP) defined as the product of plasticity index and percentage of fines less than BS No 200 sieve:

$$PP = PI * (\% < 75\mu m) \quad \cdots(3)$$

Shrinkage Modulus (SM) defined as the product of linear shrinkage and percentage passing BS No 40 sieve (% < 425 µm).

$$SM = LS * (\% < 425\ \mu m) \quad \cdots(4)$$

DISCUSSION OF RESULTS

Effect of Groundnut shell ash on the Particle Size Distribution of Black Cotton Soil

The untreated black cotton soil was pulverized and passed through BS. No. 4 Sieve as specified by Head (1980) for the purpose of removing excess clods from clayey soil. The soil was then mixed with water equivalent to its optimum moisture content (OMC) of 10.4%. This resulted in the formation of aggregates, clods, and lumps or otherwise called crumbs, in agreement with René (1971) who reported that the soil was being glued together by substances such as humus or cemented by calcium carbonate.

When various percentages of GSA were mixed with the black cotton soil thoroughly at OMC obtained at the British Standard Light (BSL) compaction energy, striking changes appeared almost instantaneously. The colour of the soil became brighter, its gloss nature duller, its plasticity reduced, and its particle size grading improved with reduction in the clods as GSA content increased.

The particle size distribution curves for both the natural and stabilized soils were shown in Figures1 and 2. It was observed that there was a great reduction in the percentage of fines with increase in GSA content. Not much change was noticed in the coarser sizes. Changes in the shapes of the curves were apparent from 0.2 to 0.002mm and more pronounced at the clay fraction. This shows that the reaction between soil and additive took place more between the GSA and the fine fraction particularly the clay minerals. The reduction in the proportion of silt or the fine fraction could be due to the bonding of the silt sizes to form pseudo-sand sizes and of the sand sizes to form larger sand or clog sizes.

The reduction in fines fraction can also be explained by the grading modulus as shown in Figure 3. As the GSA content increased the grading modulus decreased. This was consistent with the characterization of particle size, since at higher grading modulus the soil particles have lower percentages of fines passing through BS. No. 200 sieve. This implies that grading modulus is inversely related to the percentage of fines content.

Plastic Limit: The variation of plastic limit with GSA content was depicted in Figure 4. It can be observed that with each increment in GSA content, the plastic limit decreased from the initial value of 14.5 % for the natural soil to a minimum value of 7.84 % at 10 %GSA content. Further increase in GSA content led to an increase in the plastic limit to a value of 11.27 % at 12 % GSA content. The initial reduction in plastic limit with increase in GSA content is in agreement with the findings of Peter (1993), Saleh and Utpal (1993) and Osinubi (1995, 1999) and this could be due to cationic exchange reaction. The more active and higher valence cations in the GSA (i.e., Ca^{2+}) probably replaced the weakly bonded ions in the clay structure and this led to flocculation and liberation of water bonded at the outer layers.

At 10 % GSA content, a marked decrease in plastic limit to a value of 7.84 % was observed. Further increase in GSA content also increased the plastic limit to the maximum value of 11.27 %. This could be due to the increase in silicate and aluminium ions, which according to Gillott (1987) and Sherwood (1957) in the presence of moisture reacted with available sulphate (1 % or less) to form the "sulphate attack phenomenon" otherwise called "sulphate induced-heaving". The probable formation of ettringite naturally led to increase in volume and plasticity of the soil as was exhibited at 12 % bagasse ash content.

Plasticity Index: The variation of plasticity index with higher doses of GSA content was shown in Fig4. The plasticity index of the natural soil was 37.27 % and at 8 % GSA content the plasticity index increased to a peak value of 55.6 %. Further addition of GSA resulted to a decrease in the plasticity index to a minimum value of 31.5 % at 10 % GSA content. At 12 % GSA content an increase in plasticity index was observed which could be attributed to the same reasons as for the plastic limit.

Plasticity Characteristics: The other parameters associated with plasticity of the natural and treated soil are also shown in Fig 4. Generally, it was observed that plasticity modulus (PM), plasticity product (PP), and shrinkage modulus (SM) increased with higher doses of GSA, attaining optimal values at 10 % GSA content.

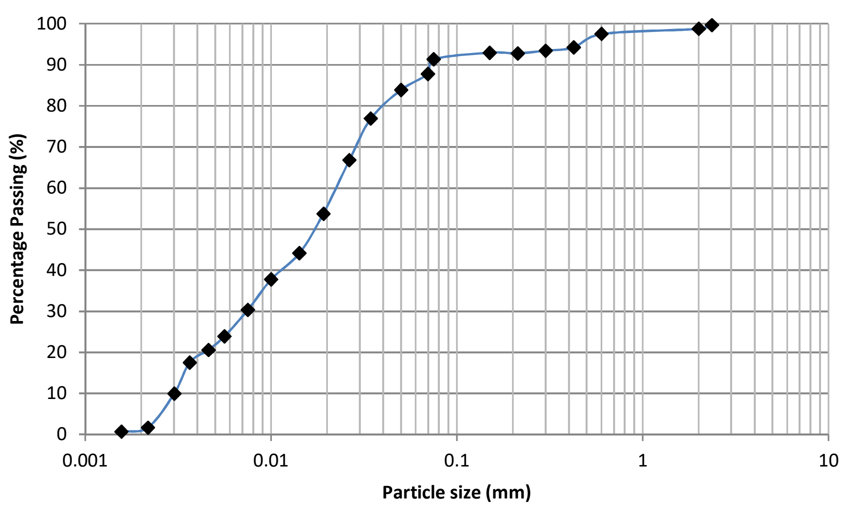

Figure 1: Particle size distribution of the natural soil

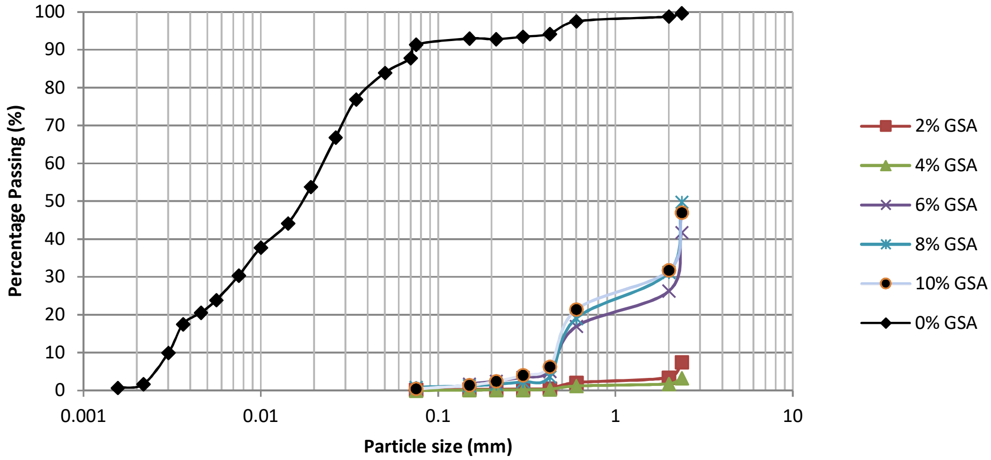

Figure 2: Particle size distribution of the natural and GSA treated black cotton soil

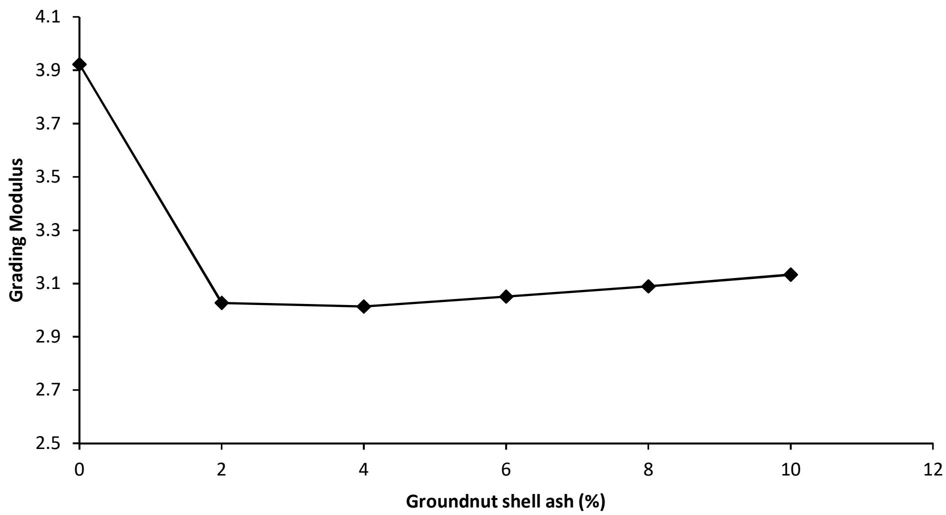

Figure 3 Variation of Grading Modulus with groundnut shell ash

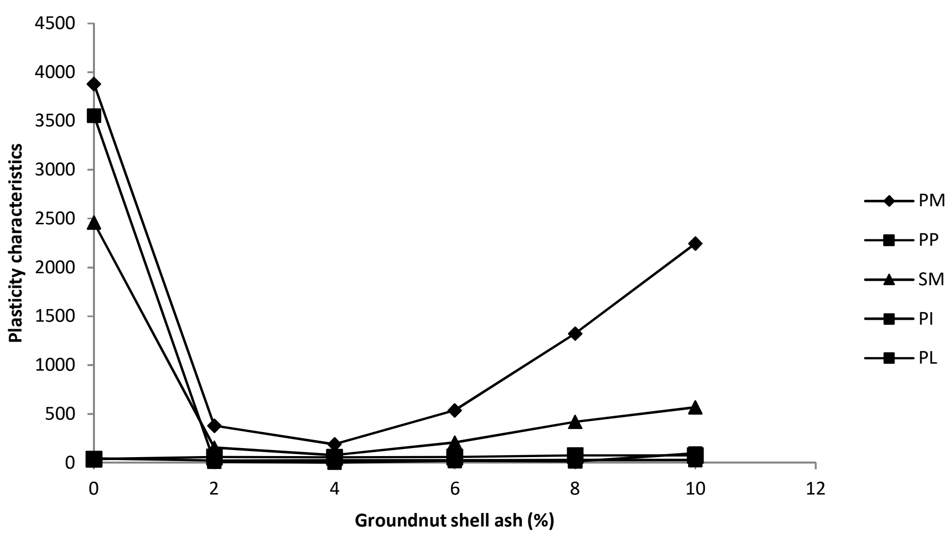

Figure 4: Variation of plasticity characteristics with groundnut shell ash

CONCLUSION

Based on the results obtained from the investigation carried out the following conclusions can be made:

1. The black cotton soil used was an A – 7 – 6 and CH soil in AASHTO and USCS classification systems, respectively.
2. The natural soil had 58 % fines passing the BS sieve No. 200, with high, plastic limit and plasticity index.
3. There was great reduction in the amount of fines fraction with higher doses of GSA by dry weight of soil. The percentage of silt fraction in the natural soil was 30 % and this was reduced to 6.4 % when treated with a maximum 10 % GSA content by dry weight of soil at the optimum moisture content (OMC).
4. The plasticity index decreased from 37.3 to 31.5 % when treated with 10 % GSA content by weight of dry soil. The results obtained place the soil below the Highway Research Board of America (1943) requirements of plasticity index and percentage passing BS sieve No. 200 less than 18, 50 per cent, respectively. However, the treated soil can be admixed with more potent stabilizer since its workability was improved by addition of 10% GSA content.

REFERENCES

Alabadan B.A., Njoku C. F. and Yusuf M. O.(2006). "The Potentials of Groundnut Shell Ash as Concrete Admixture". Agricultural Engineering International: the CIGR Ejournal. Manuscript BC 05 012, Vol. VIII. February, 2006

Balogun, L.A.(1990) "Foundation investigation and design techniques for residential buildings on expansive black cotton soils." The Nigerian Engineer. Vol. 20, No.2, pp.34-41.

Balogun L. A. (1991a). Foundation investigation and design techniques for residential buildings on expansive black cotton soils. Niger. Eng. 20(2):34-41.

Balogun L. A. (1991b). Effect of sand and salt additives on some geotechnical properties of lime-stabilised black cotton soil. Niger. Eng. 26(4):15-24

BS 1377, (1990) Methods of Testing Soil for Civil Engineering Purposes. British Standards Institute, London.

BS 1924, (1990) Methods of test for stabilized soils. British Standards Institute, London.

Charman, J.H. (1998). "Laterite in road pavements". *CIRIA Special Publication 47*, Construction Industry Research and Information Association., ed., CIRIA, London.

Czernin, W. (1962). *Cement Chemistry cnd Physics For Civil Engineers*, Crosby Lockwood, London

Gillot J.E. (1987) *Clay in Engineering Geology*. Elsevier Publishing Company, Amsterdam.

Head, K.H. (1980)*Manual of Soil Laboratory Testing Vol. 1 Soil Classification and Compaction*. Pentech Press, London, Plymouth.

Highway Research Board of America (1943) "Use of Soil – Cement mixture for Base courses." Wartime Road Problems No.7, Nat., Res. Council, Div. Eng.Indust. Res., WashingtonD.C.

Jones, D. and Holtz, J. (1973). "Expansive soils: Hidden Disaster." *Civil Engineering*, Vol. 43 pp 54.

Ola, S.A. (1983) "The geotechnical properties of black cotton soils of north eastern Nigeria". In: S.A. Ola(ed). *Tropical Soils of Nigeria in Engineering Practice*. Balkema, Rotterdam, pp 260-278

Osinubi, K.J. (1995) "Lime modification of black cotton soil." Spectrum Journal, Vol. 2, Nos. 1 and 2, pp. 112 – 122.

Osinubi, K.J (1999) "Evaluation of admixture stabilization of Nigerian black cotton soils". NSE Technical Transaction Vol. 34, No. 3, pp. 88-96.

Osinubi, K.J. (2000a) "Stabilization of tropical black clay with cement and pulverized coal bottom ash admixture". In: *Advances in Unsturated Geotechnics*. Edited by Charles D. ShackefordL.Houston and Nien-Yui Chang. ASCE Geotechnical Special Publication, No.99, pp.289-302

Osinubi, K.J. (2000b) "Laboratory trial of soil stabilization using pulverized coal bottom ash." NSE Transaction. Vol.35, No.4, pp.13-21.

Osinubi K. J. (2006). Influence of compactive efforts on lime-slag treated tropical black clay. American Society of Engineers. J. Mater. Civil Eng. pp.175-181

Osinubi, K.J. and Medubi, A.B. (1997) "Evaluation of cement and phosphatic waste admixture on tropical black clay road foundation." Proc. of 4th Int. Conf. on Structural Engineering Analysis and Modelling. (SEAM 4), Accra, Vol. 2: pp. 297-307.

Peter, G.M. (1993) "Fly ash stabilization of tropical Hawaiin soils." In: *Fly ash for soil improvement*. Geotechnical Special Publications No.36, K. D.Sharp.(ed.) Geotechnical Engrg. Division of the ASCE. pp.15-20.

René, F.V. (1971) "Immediate amelioration of wet cohesive soils by quicklime." Transportation Road Research Journal. Vol. 5. pp. 5 – 12.

Saleh, M and Utpal, D. (1993) "Stabilization of south Texas soils with fly ash". In: *Fly Ash for Soil Improvement*. Geotechnical Special Publications No.36, K. D.Sharp (ed.) Geotechnical Engrg. Division of the ASCE, pp.30-35

Sherwood, P.T. (1957) "The stabilization with cement of weathered and sulphate-bearing clays". Geotechnique, Vol. 7, pp.179-191.

Transport and Road Research Laboratory (TRRL). (1990). "Tropical soils: Formation, classification and engineering properties." Department of Environment, Her majesty's Stationery Office (HMSO), London.